Chapter 6
Spatial and Temporal Patterns in the Amount of Young Forests and Implications for Biodiversity

Stephen R. Shifley and Frank R. Thompson III

Abstract Forest inventory data provide simple indicators of forest structural diversity in the form of forest age distributions and their change over time. A result of past land use and disturbance, more than half of the 51 million ha of forest in the Central Hardwood Region is between 40 and 80 years old and young forest up to 10 years old constitutes only 5.5% of the area. Simulations of a sustained level of management over time produce more uniform (flatter) age-class distributions. A management scenario designed to maintain about 7% of total forest area as young habitat results in a region-wide young forest deficit of one million ha relative to current conditions. However, management activities that create an average of 200 ha of additional young forest per county per year would be sufficient to erase that deficit.

6.1 Introduction

Concern over the quantity, spatial distribution, and temporal distribution of early successional forest habitats is a direct result of conservation concerns for wildlife species dependent on these forest communities and for biodiversity in general. Sustaining diverse, early successional forest habitats through time and across forest landscapes is expected to improve—or at the very least to not diminish—opportunities for sustaining wildlife communities that depend upon access to them.

Early successional forests can consist of pioneer tree and shrub species in association with annual and perennial herbaceous plants colonizing former agricultural or other nonforest land. They can also be early stages of forest regeneration following harvests or other major disturbances in established forests (see Greenberg et al., Chap. 1).

S.R. Shifley (✉) • F.R. Thompson III
USDA Forest Service Northern Research Station, University of Missouri,
202 Natural Resources, Columbia, MO 65211–7260, USA
e-mail: sshifley@fs.fed.us; frthompson@fs.fed.us

C.H. Greenberg et al. (eds.), *Sustaining Young Forest Communities*,
Managing Forest Ecosystems 21, DOI 10.1007/978-94-007-1620-9_6,

Early successional forests include young forest plantations as well as natural forest regeneration, although plantations comprise only 5% of the forest area in the Central Hardwood Region. Managers often refer to these young forests as seedling- or sapling-sized forests. In the context of forest stand development, these forests are in the stand initiation stage of development (Loftis et al., Chap. 5). All these young forest communities or vegetation stages can, to varying degrees, provide habitat for early successional wildlife. If undisturbed, they will eventually progress to the stem exclusion, understory reinitiation, and old-growth stages of stand development (Oliver and Larson 1990; Johnson et al. 2009; Loftis et al., Chap. 5).

Our focus is on young or regenerating forests that are in the stand initiation stage of development. For simplicity we refer to them as young forests. In the Central Hardwood Region the dominant tree cover in these young forest habitats typically is not more than 10 years old and never more than 20 years old. Young forests are an important component of all early successional habitats in the Central Hardwood Region. Young forests can be readily established and maintained through forest management, and data on habitat abundance over time are available from the US Forest Service (Forest Inventory and Analysis 2010b). Other vegetation types, such as shrublands, provide additional habitat for early successional species, however these types are poorly inventoried (Greenberg et al., Chap. 1; Warburton et al., Chap. 13).

This chapter is organized around three topics. First, forest management practices greatly impact the amount of young forest in the landscape and how it changes over time with stand development. Whether forests are managed for wood products, biological diversity, or other ecological services or commodities, there is growing interest in sustainable forestry. We examine the availability of young forests in the broader perspective of sustainable management. We discuss how age class distributions are an indicator of sustainable management and a coarse filter for habitat diversity. Second, we consider the age distribution of forest area to be an indicator of the past, present, and future quantity of young forest habitats. We summarize forest age class distributions by state and forest type for the Central Hardwood Region. We determine the temporal trends in forest age class distributions that are likely to result from continued current patterns of disturbance, and explore management scenarios that would sustain a constant availability of young forests over time. Third, we consider how spatial and temporal distributions of young forests affect wildlife habitat quality. Using simulation modeling, we demonstrate how forest management practices and natural disturbances affect the amount and spatial pattern of forest age classes at the landscape level. For the second and third topics, we provide examples of how these patterns are related to early successional wildlife species.

6.2 Sustainable Forest Management and Age Class Diversity

Internationally accepted criteria and indicators for sustainable forest management developed under the Montréal Process (http://www.rinya.maff.go.jp/mpci/evolution_e.html) include 64 indicators (informative metrics) organized into seven Criteria (broad classes). The first criterion is Conservation of Biological Diversity. Its nine associated indicators deal with landscape-scale or ecosystem diversity, species diversity, and genetic diversity:

Ecosystem diversity

1. Area and percent of forests by forest ecosystem type, successional stage, age class, and forest ownership or tenure.
2. Area and percent of forests in protected areas by forest ecosystem type, and by age class or successional stage.
3. Fragmentation of forests.

Species diversity

4. Number of native forest associated species.
5. Number and status of native forest associated species at risk, as determined by legislation or scientific assessment.
6. Status of on-site and off-site efforts focused on conservation of species diversity.

Genetic diversity

7. Number and geographic distribution of forest associated species at risk of losing genetic variation and locally adapted genotypes.
8. Population levels of selected representative forest associated species to describe genetic diversity.
9. Status of on-site and off-site efforts focused on conservation of genetic diversity.

Although these nine indicators provide information important for characterizing forest biodiversity, there is no general agreement on which values or thresholds for a given indicator characterize forest sustainability (or a lack thereof). This situation is not particular to the Montréal Process Criteria and Indicators. Most definitions of sustainable forestry lack quantitative specificity (e.g., World Commission on Environment and Development 1987; Helms 1998, National Archives and Records Administration 2007).

Management to sustain diverse forest habitats can be a coarse filter approach for managing biological diversity. Rather than attempting to monitor individual populations of all forest associated species, the coarse filter approach provides a diversity of forest habitats. This diversity is expected to provide suitable habitats for forest-associated species, including those for which inventory data are limited (e.g., invertebrates and fungi). Coarse filter screening can be adapted to take into account the distribution of habitats across ecoregions or other relevant strata in an attempt to ensure greater dispersion of habitats (e.g., to ensure that focal habitats such as woodlands or old-growth forests are spatially distributed across multiple ecoregions).

The coarse filter approach has been used to guide establishment of protected forest areas, but it is not limited to allocation of protected forests. Coarse filter approaches are equally applicable to actively managed forests where they can be used to quantify and maintain habitat diversity. Because forest habitats change over time due to endogenous and exogenous processes and disturbances, any coarse filter approach to managing biological diversity must take into account the spatial and temporal patterns of disturbances necessary to maintain future habitat diversity (Haufler et al. 1996). The historic range of variation in habitat diversity and/or ecosystem processes (e.g., historic forest fire frequency) is sometimes used as a benchmark for judging adequacy of current habitat diversity, but that presumes a rationale for selecting a particular time in history as a desirable benchmark (see Warburton et al., Chap. 13). Benchmarks for the range of historic variation in forest ecosystems are often linked to years for which historic data happen to have been collected (e.g., during initial land surveys) rather than by other objective criteria.

Although coarse filter screening is a suitable starting point for evaluating present and future forest habitat diversity, characterization and maintenance of habitat diversity requires assessment at finer spatial scales. Thus, a hierarchical approach also includes meso-scale evaluations of habitat components (e.g., down logs, snags, seeps, riparian forests), and fine-scale evaluation of individual species, with particular emphasis on species that are at risk of extinction (Schulte et al. 2006).

A coarse filter approach to evaluating and conserving forest diversity could be applied using variables that describe forest vegetation types or stages such as age structure, overstory species composition, understory species composition, size structure, tree density, stocking percent, past disturbance regime, patch size, geographic location, ownership, or spatial juxtaposition of habitat components. However, there are some practical constraints on the process. First, variables used in a coarse filter analysis must have been inventoried across the landscape of interest. Second, the number of variables analyzed simultaneously when applying a coarse filter approach to a specific landscape must be commensurate with the capacity to manage the landscape for habitat diversity. For example, in a given forest landscape it might be desirable to maintain 20 forest age classes across each of five forest cover types with multiple spatially dispersed forest patch sizes. However, the logistics of creating and maintaining that range of structural and compositional diversity over time would likely be daunting, especially in forest landscapes with a large proportion of private ownership.

Data are readily available to support a coarse filter examination of forest age class diversity at regional and national scales (millions to hundreds of millions of hectares). Age classes are indicative of forest size class, structural characteristics, and successional stages, and all these age-associated characteristics are in turn indicative of habitat quality for key wildlife species. In the past decade, publications at local, state, regional, and national scales have reported forest age class diversity as an indicator of forest biodiversity using the Montréal Process Criteria and Indicator framework (e.g., Baltimore County 2005; Carpenter 2007; USDA Forest Service 2004).

The distribution of forest area by age class is among the simplest large-scale indicators of forest structural diversity. Such information has been applied routinely for more than a century to develop sustained yield timber management plans, and in some conservation approaches forest structural diversity is assumed to be a surrogate for wildlife diversity. Moreover, forest age or size class distributions also can be used to directly model wildlife habitat or abundance. For example, Rittenhouse et al. (2007) and Tirpak et al. (2009) used forest age class or size class for individual sites (e.g., 0.01 ha) and for collections of sites describing the surrounding landscapes as key variables in habitat suitability models for wildlife. Twedt et al. (2010) used county-level estimates of forest area by size-class from the Forest Inventory and Analysis program as covariates to predict bird abundance as measured by the North American Breeding Bird survey. In this volume, Franzreb et al. (Chap. 9) relate trends in bird abundance to trends in forest age classes.

6.3 State and Regional Forest Age Class Distributions

We assessed forest age class distributions for ten states that fall mostly in the Central Hardwood Region: Arkansas, Illinois, Indiana, Kentucky, Michigan, Missouri, Ohio, Pennsylvania, Tennessee, and West Virginia (see McNab, Chap. 2; Fig. 2.1). We utilized state-wide inventory data to examine forest age-class structure by state, for multiple states, and by forest type. The Forest Inventory and Analysis (FIA) division of the US Forest Service inventories the nation's forests in detail and publishes state, regional, and national summaries (e.g., Woodall et al. 2006; Smith et al. 2009, Forest Inventory and Analysis 2010a). Moreover the data and associated summary, mapping, and analysis tools are publicly available online (Forest Inventory and Analysis 2010b). In addition to measures of current forest conditions, there are temporal records for some forest characteristics that extend back as far as 50 years for some states. To the extent possible we utilized the FIA EVALIDator tool (Miles 2010) for data summaries; it automatically applies the appropriate weights to expand plot-level data to area wide estimates while taking into account the three-phase, stratified, FIA sampling design.

Estimation of forest characteristics using FIA data is not restricted to individual state totals. Forest area, volume, and number of trees can be readily summarized by county, groups of counties within or among states, groups of states, congressional districts, ecoregions, or other user-specified geographic regions. Summaries for any geographic region can be further subdivided by species group, age class, tree size, site quality, or other variables of interest. However, as the sampled area and number of inventory plots included in any subcategory decreases, the standard error of the estimate for that subcategory increases. We concentrated primarily on state-level summaries for two reasons. First, some historical forest resource data are available only as state-wide summaries, so some historical trends can only be summarized at the state scale. Second, state forestry or natural resource agencies will be key to designing and implementing any future policies or management practices intended to create or maintain early successional forest habitats within their jurisdiction.

We summarized the current forest area by age class for each state and by forest cover type across all 10 states. For the various age class distributions we computed rates at which forest regeneration would need to occur (i.e. hectares regenerated per decade) to periodically replenish and maintain alternative amounts of young forest habitat. Specifically, for scenarios that set aside differing levels of undisturbed forest (e.g., 10% or 20% of all hectares) we computed the amount of additional young forest that must be created (or avoided) to sustain a constant area of young (20 years or less) forest over time. Finally, for one selected state within the study region—Indiana—we examined changes in forest age distributions over time by compiling time series information from previously published inventory reports.

6.3.1 Forest Age Classes by State

The ten states examined in this analysis have, combined, 51 million ha of forest land, or 17% of all US forest land (Table 6.1). Forests cover 43% of the land area in the 10-state region, and oak-hickory (*Quercus-Carya*) and maple-beech-birch (*Acer-Fagus-Betula*) forest types cover more than two-thirds of the forest area. The distribution of forest area by age class across the study region is distinctly unimodal (Fig. 6.1). Across the ten states, 60% of the total forest area is between 40 and 80 years of age. State entries in Fig. 6.1 are ordered from those with the least forest area in the 0–10-year old age class (Illinois) to the greatest (Arkansas).

Individual states vary from two to eight million ha in total forest area. Viewing the distribution of forest area by age class on a percentage basis normalizes differences in total forest area (Fig. 6.2). The shapes of the forest age distributions for the ten states are remarkably similar. Maximum forest area by 10 year age classes ranges from 17% to 21% and consistently occurs in ages classes from 50 to 80 years.

We grouped states with similarly shaped age class distributions for forests less than 30 years of age (i.e., similar left tails of the age class distribution) (Fig. 6.2). Arkansas, Tennessee, and Ohio have greater area in the 0–10 year age class than in the 11–20-year age class (Fig. 6.2a). That pattern is less pronounced for Kentucky, Indiana, Illinois, and West Virginia (Fig. 6.2c). For Michigan and Missouri the proportion of forest area increases with increasing age through at least age 50 (Fig. 6.2c), and Pennsylvania forests have a similar trend.

These age class distributions are the cumulative effect of past forest disturbances. Stand-initiating disturbances (Oliver and Larson 1990; Johnson et al. 2009) are those that remove enough of the existing forest overstory to regenerate a new stand and reset the age of the dominant forest cover to zero. Based on the age-class distributions (Fig. 6.2), stand-initiating disturbances in this region were common 50–80 years ago, affecting at least 15–20% of the area per decade. In the past two decades, stand-initiating disturbances affected 3–10% of the forest area per decade with considerable variation among states.

Table 6.1 Forest area by state, ownership and forest type group in the Central Hardwood Region, 2011. States are ordered from greatest to least proportion of forest land

State	Land area (hectares)	Forest land area (hectares)	Forest land %	Private forest land ownership %	Oak-hickory	Maple-beech-birch	Elm-ash-cottonwood	Loblolly-shortleaf pine	Oak-pine	Aspen-birch	Spruce-fir	White-red-jack pine	Other forest type groups
West Virginia	6,240,891	4,847,917	78	87	75	18	1	1	2	0	0	1	2
Pennsylvania	11,612,551	6,741,788	58	71	54	33	2	1	1	2	0	2	5
Arkansas	13,491,498	7,497,856	56	80	42	0	5	29	11	0	0	0	13
Michigan	14,686,235	8,024,840	55	62	16	29	10	0	3	17	13	10	2
Tennessee	10,684,211	5,619,919	53	85	72	2	5	6	8	0	0	1	6
Kentucky	10,293,927	5,007,784	49	89	75	8	6	2	5	0	0	0	4
Missouri	17,851,417	6,233,550	35	83	82	1	7	1	6	0	0	0	3
Ohio	10,610,121	3,256,615	31	87	63	21	9	1	1	1	0	1	3
Indiana	9,303,644	1,920,712	21	84	73	8	12	1	2	0	0	1	3
Illinois	14,416,194	1,942,376	13	83	71	1	23	1	1	0	0	1	2
Total All States	119,190,688	51,093,358	43	79	58	13	6	6	5	3	2	2	5

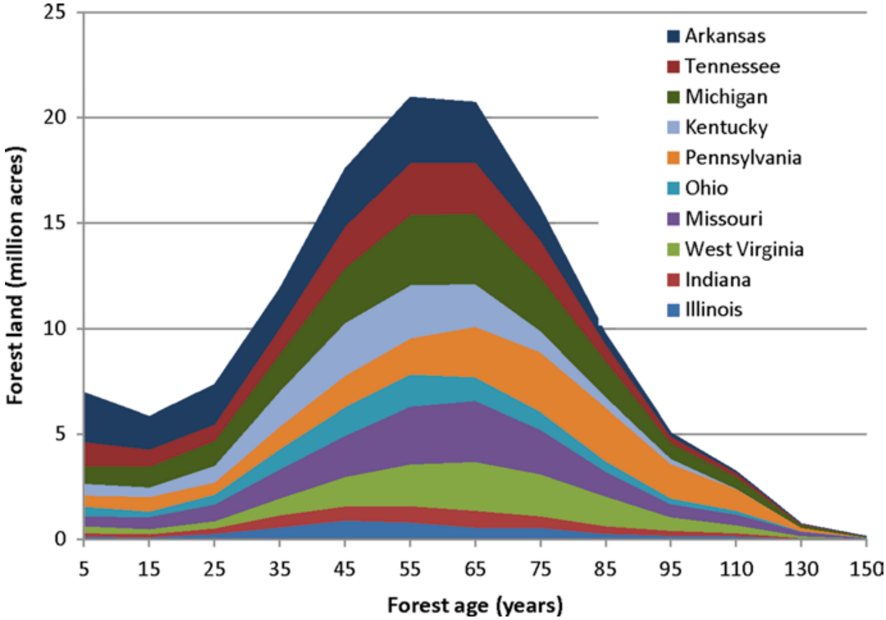

Fig. 6.1 Forest area by 10-year age classes for ten states in the Central Hardwood Region. Individual states are shown as stacked colored areas and the total area is represented by the top of the distribution States are ordered from the least (Illinois) to the most (Arkansas) total area in the youngest age class (0–10-years old)

6.3.2 Forest Age Classes by Forest Cover Type

Forest cover types are based on species composition of the dominant tree cover (Helms 1998; Eyre 1980). The forest cover type—sometimes referred to simply as the cover type or the forest type—is determined by the group of associated species with a plurality of the stand stocking or basal area. We used FIA naming conventions to summarize forest area by eight forest type groups (Table 6.1) that consolidate rare forest types with more common ones. These groups are the focus of the region-wide analyses reported in this section. We omitted nine additional groups that occur within the study region but make up 1% or less of the total forest area.

The age distributions for most forest type groups in the Central Hardwood Region (Fig. 6.3) have unimodal shapes similar to those observed for state-wide summaries across all groups (Fig. 6.2). The notable exception is the loblolly-shortleaf pine (*Pinus taeda-P. echinata*) group, which has decreasing forest area with increasing forest age. Within the Central Hardwood Region this group is concentrated in Arkansas, where half the area is in plantations and half is in natural stands. The planted loblolly-shortleaf stands are predominantly less than 30 years old, and the natural stands are predominantly greater than 30 years old. For this forest type group intensive management in the last three decades has been highly influential in shaping the age class distribution through extensive establishment of forest plantations.

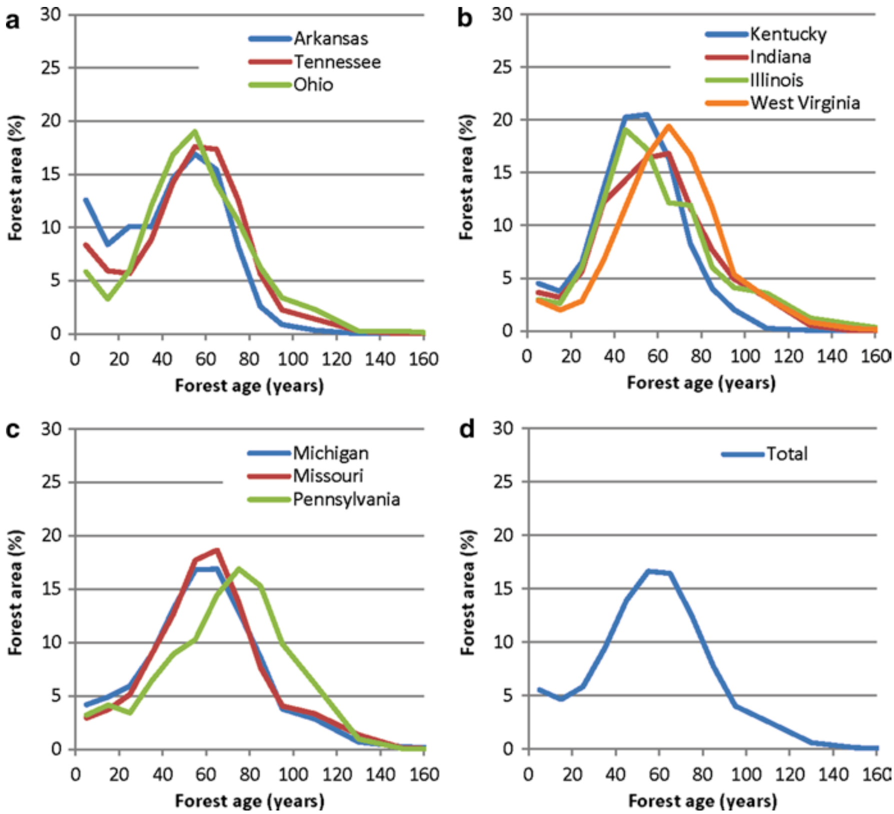

Fig. 6.2 Percent forest area by 10-year age classes for states in the Central Hardwood Region. Panels (**a**), (**b**), and (**c**) display groups of states that are similar in the shape of their age class distributions for forest less than 30 years old

In naturally regenerated forests the forest type groups and forest age classes are interrelated in two important ways. First, some groups are dominated by early successional tree species that are generally favored by a stand-initiating disturbance. Aspens (*Populus tremuloides*; *P. grandidentata*) and birches are relatively short-lived pioneer species that tend to increase in abundance on heavily disturbed sites within their range. As aspen-birch forests age, late successional species such as white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), or sugar maple (*A. saccharum*) often increase in dominance. In the absence of disturbance those species can subsequently dominate the forest cover. Consequently, forests in the aspen-birch forest type group tend to be young relative to those in the maple-beech-birch or spruce-fir forest type groups. Figure 6.3b illustrates this forest-type-group by age progression from early successional aspen-birch and elm-ash-cottonwood (*Ulmus-Fraxinus-Populus*) groups with relatively short-lived species to the late successional oak-hickory and maple-beech groups with relatively long-lived species. Second, the silvicultural systems typically associated with a forest cover type affect the age structure. Intensive plantation management contributes to the abundance of young loblolly-shortleaf forest area.

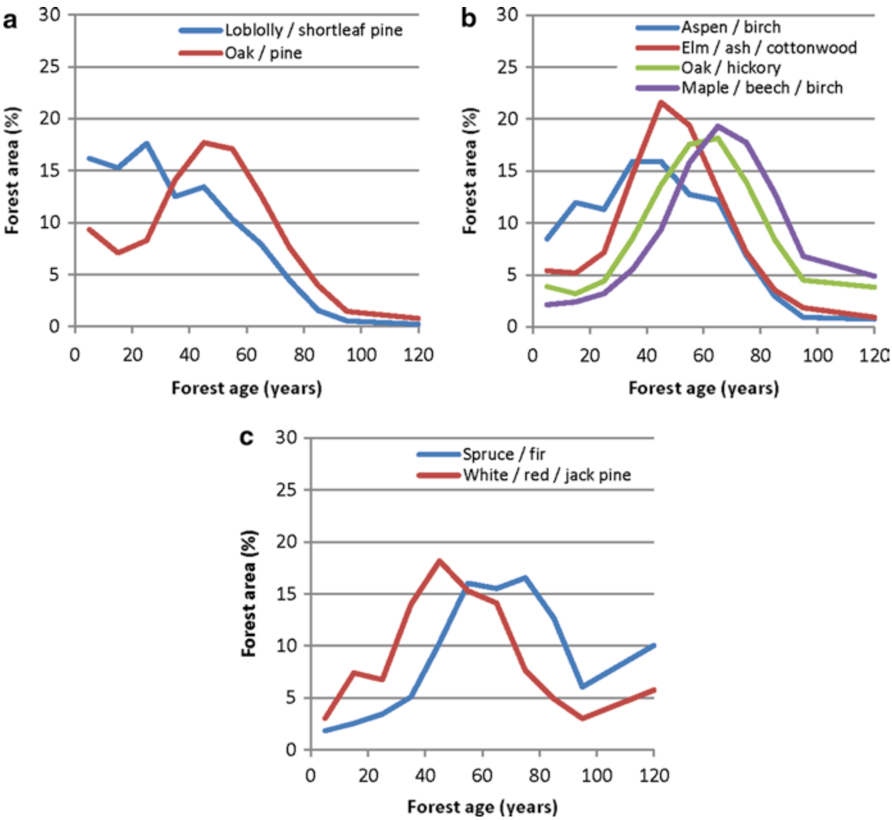

Fig. 6.3 Percent of total forest area by 10-year age class and forest type group for ten states in the Central Hardwood Region. Panel (**a**) displays the two forest type groups with the greatest relative area in the 0–10-year age class. Panel (**b**) illustrates increasing mean and peak forest age class for five hardwood forest type groups. Panel (**c**) shows age distributions for the remaining two conifer forest type groups. The composite age distribution for all forest type groups is identical to Fig. 6.2(**d**)

Short-rotation, even-aged silviculture with clearcutting is commonly used to regenerate aspen-birch forests. Thus, they tend to be relatively young compared to oak-hickory and maple-beech forests that are typically managed on longer rotations with crop tree management and harvest by individual-tree selection.

6.3.3 *Forest Age Classes Over Time*

The shape of an age class distribution (Figs. 6.1–6.3) reflects the accumulated history of past patterns of stand initiating disturbances for that population. For example, forests currently in the 60-year age class (young sawtimber) underwent a stand initiating disturbance 60 years ago and have not had a subsequent stand initiating disturbance since.

For some individual states it is possible to combine periodic forest inventories over a nearly 60 year period to directly observe changes over time in forest age-class distributions. Indiana lies in the center of the study region and is typical among states that have low abundance of early successional forests (Fig. 6.2). Statewide forest inventories for Indiana were conducted in 1950, 1969, 1986, 1998, 2003, and 2008 (USDA Forest Service 1953; Spencer 1969; Miles 2010). Early forest inventories reported values for timberland rather than forestland, so for consistency we also summarized area of timberland. Timberland excludes forested parks, wilderness areas, and other locations where timber harvest is restricted by policy or legislation. It also excludes areas that are so unproductive or physically inaccessible that commercial harvest operations are impractical. For Indiana statewide summaries this distinction is of little practical significance because 98% of all forest land in the state is classified as timberland. Between 1950 and 2008, total timberland area in Indiana increased from 1.6 to 1.9 million ha, largely due to natural forest regeneration on land that was previously used for agriculture. More than 95% of the state's timberland is in hardwood forest types. Inventories prior to 1998 recorded stand size class rather than age class. To maintain continuity across all inventory years we summarized Indiana forest area by three size classes:

- Seedling/sapling —stands with more than half the stocking in trees between 3 and 13 cm diameter at breast height (dbh). These stands are typically less than 30 years of age.
- Poletimber—stands with more than half the stocking in the combined poletimber (13–28 cm dbh) and sawtimber (>28 cm dbh) size classes with poletimber stocking exceeding sawtimber stocking. These stands are typically 30–60 years of age.
- Sawtimber—stands with more than half the stocking in the combined poletimber and sawtimber size classes with sawtimber stocking equal to or greater than poletimber stocking. These stands are typically at least 60 years old.

The time series from 1950 to 2008 reveals a steady increase in forest in the sawtimber size class (Fig. 6.4). The proportion of young forest represented by the seedling-sapling size class peaked at 24% in 1967, declined to 6% by 1998, and gradually increased to the current level of 8%. The poletimber size class varied in proportion over time as ageing forests in the seedling-sapling size class moved into the poletimber size class and aging forests in the poletimber size class moved into the sawtimber size class.

Abundance of several wildlife species in Indiana that are dependent on early successional habitats have declined precipitously and show a general correspondence with the decline of seedling-sapling forest from its peak in 1967 (Fig. 6.5). Prairie Warblers (*Dendroica discolor*) have steadily declined since monitoring by the North American Breeding Bird Survey began in 1966 (Sauer et al. 2008); American Woodcock (*Scolopax minor*) since monitoring by the Singing-ground Survey began in 1968 (Cooper and Parker 2010), and Ruffed Grouse (*Bonasa umbellus*) since monitoring by drumming routes began in 1979 (Backs 2010). The less than perfect correspondence among these curves could reflect that all are estimates and that habitat is not the sole determinant of bird abundance (also see Franzreb et al., Chap. 9).

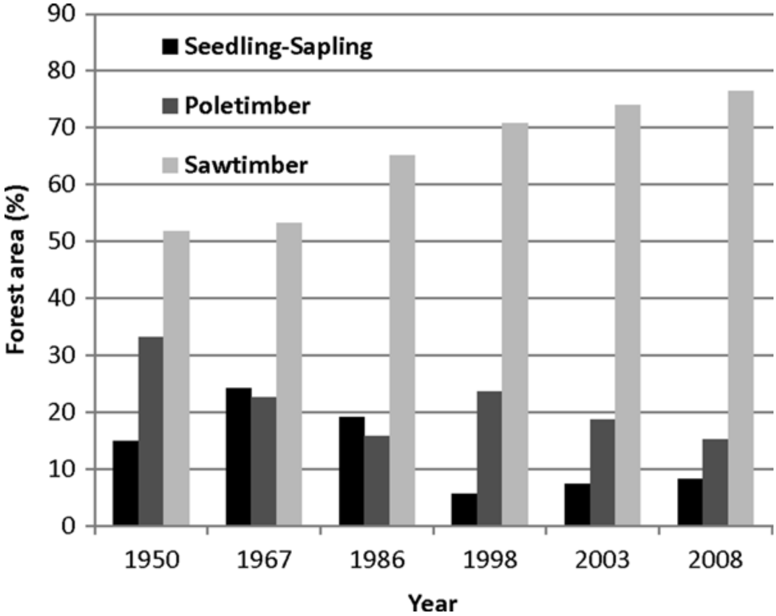

Fig. 6.4 Timberland area by stand size class and inventory year, Indiana. Forests in the seedling-sapling size class are stocked predominantly with trees less than 13 cm dbh. Forests in the poletimber size class are stocked predominantly with trees at least 13 cm and less than 28 cm dbh. Forests in the sawtimber size class are stocked predominantly with trees 28 cm dbh and larger

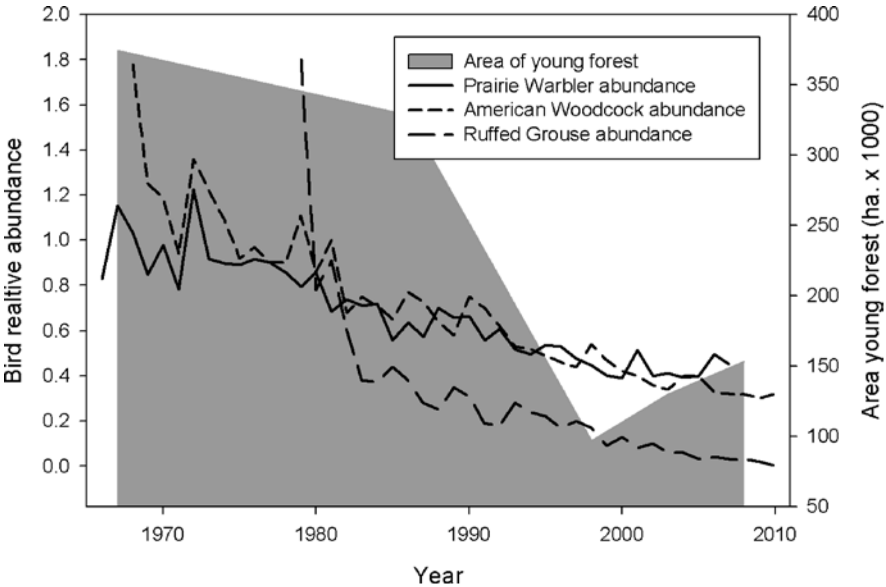

Fig. 6.5 Trends in Prairie Warbler, American Woodcock, and Ruffed Grouse from roadside surveys in Indiana and area of young forest (seedling-sapling class, Fig. 6.4)

6.3.4 Scenario Analyses

Early successional forest habitats are created by disturbances that regenerate a new forest stand, or they develop from open land that is allowed to succeed to forest cover. A given tract of early successional forest is transient; generally it will grow into mid-successional habitat within 20 years (see Greenberg et al., Chap. 1). Thus, sustaining early successional habitats on a forest landscape requires periodic disturbances that regenerate new forest stands and thereby recreate young forest habitats; these events can be forest management activities (e.g. tree harvest, prescribed fire) or natural events (e.g. wind, wild fire) (White et al., Chap. 3). Sustaining polesize forest habitats (e.g., 30–60-year-old forests in the stem exclusion stage of stand development) depends on a steady supply of seedling-sapling habitats that over time becomes polesize forest habitats. Likewise, older forest in the sawtimber size class requires a progression over time from undisturbed younger habitats. In stark contrast to old forest habitats, which require more than a century with minimal disturbance to develop, silvicultural treatments can quickly create young forest habitats via timber harvesting (see Loftis et al., Chap. 5), often with income from an associated timber sale.

Scenario analyses provide one way to examine rates of disturbances necessary to continuously replenish young forest habitats without depleting late successional forest habitats. Scenario outcomes can be compared with actual recent rates of stand initiation that are reflected in the current area of forest in the 0–20-year age class. Such comparisons can be used to estimate how much additional young forests should be created (or avoided) in order to sustain a stable total area of young forest over time.

The forest age class distributions (Figs. 6.1–6.3) reveal that both young forest habitats and old forest habitats are in short supply. Therefore, we constrained the scenarios to maintain a fixed proportion of the total forest area in age classes older than 120 years while balancing younger age classes to also sustain a constant proportion of forest habitats less than or equal to 10 years of age. Specific assumptions are as follows:

1. Dedicate 15% of total forest area to become old forest habitats (>120 years old, on average, but potentially varying by forest type, geographic location, and other factors).
2. Manage to evenly distribute the remaining forest area (85% within age classes less than 120 years) to (a) periodically replenish young forest habitats 10 years old or younger, (b) provide a uniform distribution of habitat in age classes 10–120 years, (c) maintain a pool of mature forest to serve as a replacement for old forest when it is lost to natural disturbances, and (d) increase forest habitat diversity (i.e., coarse scale age and structural diversity) compared to current forest conditions.
3. The current proportion of forest area 20 years of age or younger is a reasonable indicator of recent rates of early successional habitat creation by natural and anthropogenic disturbances over the past two decades.

4. The difference between (a) current rates of forest regeneration (assumption 3) and (b) equilibrium rates of forest regeneration derived from assumptions 1 and 2 is (c) the additional quantity of early successional habitats that should be created (or avoided) to move toward balanced forest age classes with a steady supply of young forest habitats over time.

The first two assumptions dictate that 15% of forest area is devoted to old forest habitats (older than 120 years) protected from harvest, and the remaining 85% of forest area is split evenly among twelve 10-year age classes from 0 to 120 years of age. Thus, keeping 7.1% of the forest area in young forest (up to 10 years old) and eventually in every 10-year age class up to 120 years would move the forest age distribution toward an equilibrium with greater age class diversity than currently exists.

Expressed more generally

$$Y_{eq} = (1 - R)/(0.1A_{min}) \qquad (6.1)$$

Where

Y_{eq} = the equilibrium proportion of total forest area to be maintained in each 10-year age class for the scenario. This is also the target proportion of young forests (i.e., forests less than or equal to 10 years old).

R = proportion of total forest area set aside in old forests or other protected forest areas that are excluded from management for early successional habitats.

A_{min} = minimum age for old forests in years

An alternate scenario with 20% old forests or other reserves and a 100 year minimum age for old forests results in a decadal target of 8% of forest area in young forest habitats. Similarly, assumptions of 30% old forests and other reserves with a 150 year minimum age for old forests indicate an equilibrium of 4.7% in young forest habitats per decade.

Comparison of the current proportion of young forest habitats for a given state or region to the target proportion indicated by a particular scenario indicates the deficit (or excess) of early successional habitats relative to that norm (Table 6.2). For the initial scenario with 15% of the forest area retained in old forest reserves and 120 years as the minimum age for old forests, roughly 3.6 million ha of young forests (up to 10 years old) should be established across the region each decade to maintain steady replenishment of young forest habitats. By extension, this assumes that roughly 3.6 million ha of forests will be maintained in each age class up through age 120 years. For this scenario the target by state for young forest area ranges from a low of 136,000 ha per decade in Indiana to a high of 568,000 ha per decade in Michigan (Table 6.2, column [f]). The difference by state between the target and current observed area of young forest habitats (0–10-year age class) ranges from a deficit of roughly 230,000 ha for Missouri, Pennsylvania and West Virginia to a surplus of about 250,000 ha for Arkansas (Table 6.2, column [h]). Area of young forests for Tennessee is currently very close to the target for this scenario.

Table 6.2 Young forest habitat target and observed surplus (or deficit) habitat by state for a scenario of 15% reserved forest (no harvest disturbance), a minimum old-growth habitat age threshold of 120 years, and the target area of young forest habitats (0–10 years old) computed as an equal proportion of the forest area 0–120 years old (see Eq. 6.1). Deficit or surplus area of young forest habitats is reported as a percent and as total area relative to the current area of young forest habitats. States are ordered from greatest percent deficit to greatest percent surplus of young forest habitats relative to the target (Column [e]). Under this scenario all states except Tennessee and Arkansas are presumed to be deficient in young forest habitats. Surplus or deficit area of young forest habitats on a county basis provides an indication of the annual management implications of addressing the surplus or deficit for the scenario if the forest regeneration treatments were distributed throughout the state on a county basis. Current forest area in the 0–10 and 11–20 year age classes are provided as points of reference indicating recent observed rates of stand initiating disturbances that create young forest habitats; column [g] is the mean of columns [k] and [l]

[a] State	[b] No of counties	[c] Target young forest area for the 0–10 year age class[a] (%)	[d] Observed young forest area for the 0–10 year age class[b] (%)	[e] Difference of observed and target young forest area in the 0–10 year age class (%)	[f] Target young forest area for the 0–10 year age class[a] (ha)	[g] Observed young forest area in the 0–10 year age class[b] (ha)	[h] Difference of observed and target young forest in the 0–10 year age class (ha)	[i] Deficit or surplus young forest habitat needed to meet target (ha/year)	[j] Additional young forest habitat needed annually per county to meet target (ha/year)	[k] Current area in 0–10 year age class (ha)	[l] Current area in 11–20 year age class (ha)
W. Virginia	55	7.1	2.4	–4.7	343,394	117,139	–226,255	–22,626	411	138,337	95,940
Illinois	102	7.1	2.8	–4.3	137,585	54,299	–83,286	8,329	82	57,687	50,911
Missouri	115	7.1	3.3	–3.8	441,543	207,047	–234,496	–23,449	204	182,213	231,881
Indiana	92	7.1	3.4	–3.7	136,051	65,433	–70,618	–7,062	77	70,070	60,796
Pennsylvania	67	7.1	3.7	–3.4	475,722	247,306	–228,416	–22,842	341	215,940	278,672
Kentucky	120	7.1	4.1	–3.0	354,518	206,560	–147,959	–14,796	123	225,105	188,014
Michigan	83	7.1	4.5	–2.5	568,426	364,067	–204,359	–20,436	246	334,746	393,388
Ohio	88	7.1	4.5	–2.5	230,362	147,706	–82,657	–8,266	94	189,930	105,482
Tennessee	95	7.1	7.1	0.0	397,741	400,094	2,353	235	0	467,696	332,492
Arkansas	75	7.1	10.5	3.4	531,098	785,440	254,343	25,434	0	942,566	628,315
Total	892	7.1	5.1	–2.0	3,616,440	2,595,091	–1,021,349	–102,135	1,236	2,824,290	2,365,891
Mean per State		7.1	4.6	–2.4	361,644	259,509	–102,135	–10,213	123	282,429	236,589

[a]Based on the scenario described in the table caption, 7.1% of the total forest area per state should be maintained as early successional forests in the 0–10 year age class

[b]Observed area of early successional habitats in the 0–10 year age class was computed as the average per decade observed for the 0–10 year and the 11–20 year age classes from columns [k] and [l], respectively. This provided a larger sample size than relying solely on data for the 0–10 year age class

On an absolute scale most states have large deficits in area of early successional forests relative to this scenario (Table 6.2) and, in fact, relative to any semblance of a balanced age class distribution (Figs. 6.1–6.3). However, when the deficits in early successional forest habitats are spread out across a state on an annual basis, they appear more manageable. For example, on a per county basis for an average county the total area of additional early successional habitats needed is about 100–400 ha annually (Table 6.2, column [j]). That quantity of early successional habitats can be achieved by the equivalent of a few to few dozen timber harvests per county each year. Obviously, in a practical implementation of this scenario, the total area of young forest habitats would be greater in areas with greater total forest cover. Nevertheless, the average proportion of forest area regenerated to young forest habitats in a given region for a given year would be about 0.007.

6.4 Landscape-Level Effects of Management and Disturbance

We used a landscape simulation model to demonstrate the landscape-scale cumulative effects of forest management and disturbances on forest age class distributions. We present results from simulations applied to a 71,142 ha portion of the Mark Twain National Forest, Missouri, in the Western Dry Subregion of the Central Hardwood Region (McNab, Chap. 2). Shifley et al. (2006) previously reported results for these simulations including species composition by forest size classes and dominant species group across the landscape. Here we present age-class distributions to illustrate the cumulative effects of alternative choices among silvicultural methods and management practices that can be used to used to create young forest habitat. We paid particular attention to the effects on patch size distributions for young forest age classes because for some species of conservation concern the size and spatial arrangement of young forest patches is as important as the total area of young forests.

We applied LANDIS version 3.6 (He and Mladenoff 1999; Mladenoff and He 1999; He et al. 2005) to simulate forest vegetation response to disturbance by timber harvest, wind, and fire. Details of our parameterization of LANDIS are provided in Shifley et al. (2006). Simulations were conducted for five management scenarios: uneven-aged management with group selection harvest affecting 5% and 10% of the landscape per decade, even-aged management with clearcut harvest affecting 5% and 10% of the landscape per decade, and no harvest. All scenarios included natural disturbance by wildfire (based on a 300-year mean wildfire return interval) and wind (based on an 800-year mean blowdown return interval) (Shifley et al. 2006). We reported results for year 200 of the scenarios because by that point in the simulation the age distributions and associated spatial patterns had equilibrated with respect to the assumptions of the scenario. We also reported the proportion of forest in 10-year age classes and the patch size distribution for forest 0–20 years old.

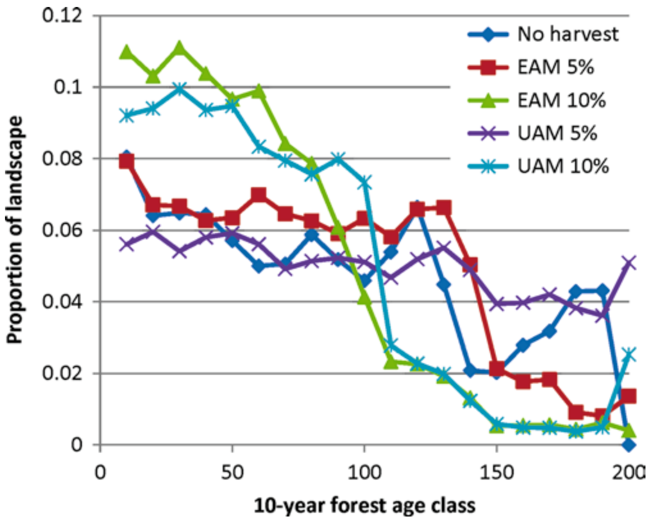

Fig. 6.6 Forest age class distributions following 200 years of simulated management and natural disturbance on a portion of the Mark Twain National Forest in the Missouri Ozarks. Age classes were summarized for each 0.01 ha site across the 71,142 ha modeled landscape. Scenarios represent no tree harvest and even-aged management (EAM) or uneven-aged management (UAM) that harvests 5% or 10% of the landscape per decade

The age class distributions resulting from our landscape simulation scenarios (Fig. 6.6) were much flatter than the current age class distributions observed by state and forest cover type (Figs. 6.1–6.3) because the scenarios implemented a consistent disturbance and management regime applied over a period of 200 years. This simulated pattern of future disturbance is very different than the actual history of timber harvest in the region over the last 200 years which was punctuated by widespread exploitive timber harvesting in the late 1800s and early 1900s.

Not surprisingly, 10% harvest per decade produces more young forest than 5% harvest per decade or no harvest (Fig. 6.6). Perhaps more unexpected is the similarity in age class distributions for no harvest and 5% even-aged or uneven-aged management. Two factors contribute to this similarity. First, the wildfire and wind disturbances modeled in the scenario affect, on average, 4.6% of the landscape per decade. Modeled wind and wildfire events in the scenarios do not always result in total loss of overstory with a stand initiating event, but over many decades the simulated wind and fire events forecast the creation of young forest habitats (see Spetich et al., Chap. 4; White et al., Chap. 3). The same is true in reality and such inevitable natural disturbances should be figured into management programs intended to maintain a specific proportion of the landscape in young forest habitats. Second, the initial conditions for the modeled scenarios are based on the observed forest age structure in the year 2000. Thus, the initial age distribution is similar to that for Missouri as shown in Fig. 6.2c. Over the 200 years of the modeled scenarios, tree species on some sites were predicted to suffer age dependent mortality when their typical

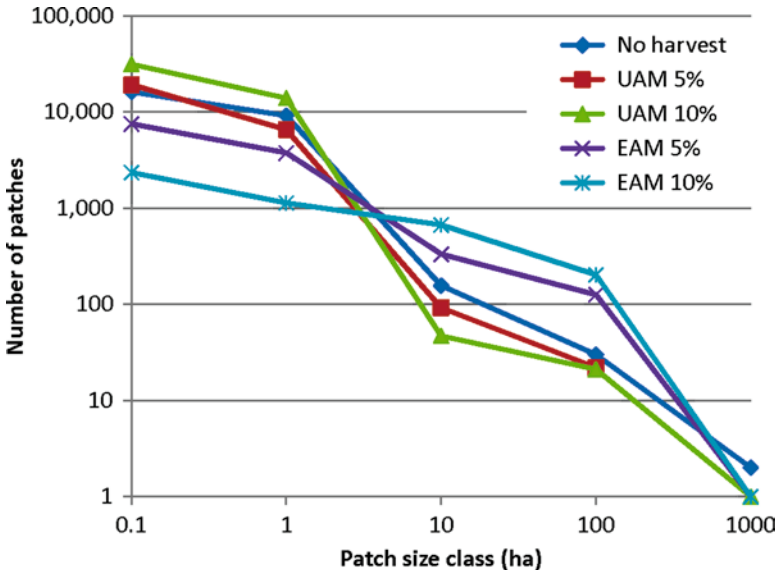

Fig. 6.7 Patch-size distribution for seedling-sapling size forest resulting from 200 years of simulated management and natural disturbance on a 71,142 ha portion of the Mark Twain National Forest in the Missouri Ozarks. Scenarios represent no tree harvest and even-aged management (EAM) or uneven-aged management (UAM) that harvests 5% or 10% of the landscape per decade

species longevity was exceeded. In certain situations this modeled natural mortality can result in initiation of a new, young forest stand.

Age-class distributions, however, do not indicate anything about spatial distribution of forests within estimation units, e.g., states. The simulated management regimes produce different patch-size distributions of young forests (Loftis et al., Chap. 5); these are evident when graphed (Fig. 6.7) or mapped (Fig. 6.8). Both the amount and spatial pattern of young forests affect habitat quality for early successional species such as the Prairie Warbler (Fig. 6.9). Higher intensity of harvest results in more young forests and generally results in higher overall levels of habitat suitability for this species. However, Prairie Warblers avoid small patches of young forests and favor large patches. Consequently, even-aged management with clearcutting results in larger patch sizes, providing substantially better Prairie Warbler habitat than a comparable total area of young forest distributed among many small patches as in the uneven-aged management regime with group selection harvesting. By contrast, the Hooded Warbler (*Wilsonia citrina*) inhabits older forests but uses small gaps in the forest; its habitat suitability is greater under uneven-aged management with group selection harvests that create small regeneration openings in the forest canopy. Estimated habitat suitability for the mature forest-associated Ovenbird (*Seiurus aurocapillus*) is largely unaffected by patch size. Similar habitat relationships exist for tree species that are characterized by their dependence on disturbance (Johnson et al. 2009).

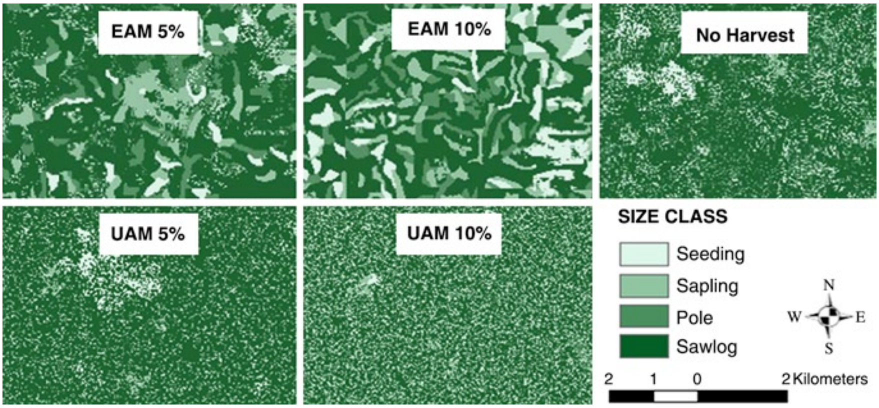

Fig. 6.8 Maps of forest patches by tree size class for landscapes resulting from 200 years of simulated management and natural disturbance on a 2,835 ha portion of the Mark Twain National Forest in the Missouri Ozarks. Scenarios represent no tree harvest and even-aged management (EAM) or uneven-aged management (UAM) that harvests 5% or 10% of the landscape per decade. The seedling size class includes forest up to 10 years old, sapling 11–30 years old, pole, 31–59 years old, and sawlog ≥60 years old (adapted from Shifley et al. 2006)

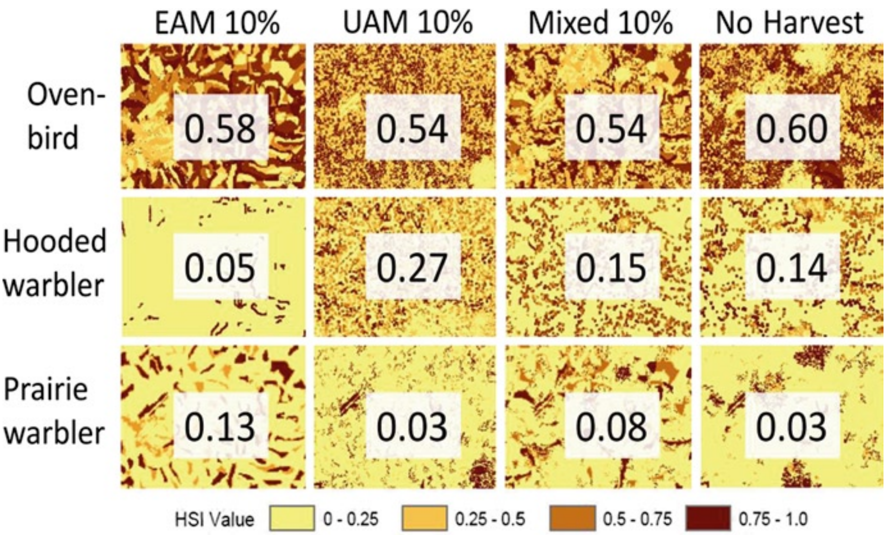

Fig. 6.9 Mean habitat suitability and maps of habitat suitability for three bird species from 200 years of simulated management and natural disturbance on a 2,835 ha portion of the Mark Twain National Forest in the Missouri Ozarks. Scenarios represent no tree harvest and even-aged management (EAM) or uneven-aged management (UAM) or an even mix of EAM and UAM (Mixed) that harvested 10% of the landscape per decade (adapted from Shifley et al. 2006)

6.5 Discussion and Conclusions

Summaries of forest age class distributions in the Central Hardwood Region reveal a paucity of young forests for most states and most forest types. More than half of the 51 million ha of forest area in the region is between 40 and 80 years of age. Only 25% of forest area is in stands between 0 and 40 years of age, and young forests up to 10 years of age constitute only 5.5% of the forest area. Nevertheless there is considerable variation in the proportion of young forests among states and forest types. Five states (Illinois, Indiana, Missouri, Pennsylvania, and West Virginia) have less than 4% of forest area in young forests while Arkansas has more than 10%. Consequently, any efforts to increase young forests will likely vary among states in magnitude and urgency.

No doubt managers will differ in opinions about how much young forest is desirable or necessary. However, it is relatively easy to examine scenarios with differing levels of old forest reserves and differing harvest rotation ages to explore alternatives for maintaining young forests. One scenario on which we focused suggested maintaining about 7% of total forest area as young forests in the 0–10 year age class. Under that scenario there is currently a region-wide young forest deficit of one million ha (Table 6.2). However that presumed deficit is unequally distributed among states and forest types.

The changes in management practices necessary to address a region-wide one million ha deficit of young forest can appear overwhelming in aggregate. However, when recast as the potential affected area per year distributed across all counties within a given state, the effort required to maintain young forest is less daunting. Given recent rates of forest disturbance and associated creation of young forests, management activities that created additional young forests in the amount of 200 ha per county per year would be sufficient, on average, to increase the region-wide proportion of these early successional habitats to more than 7% of total forest area. A potentially larger problem is continuing to periodically monitor the need for additional young forest habitats by region, state, and forest type, and annually creating additional young forest habitats where they are in deficit. Ultimately uncertainties about where, in what patch sizes, and in what forest types to create additional young forest habitats to maximize benefits to wildlife will present greater complexities than understanding how much total additional habitat is needed or the logistics of how to create it at a selected site.

Success or failure in sustaining young forests can be determined by the success or failure of wildlife species that depend upon these forests, although we acknowledge that factors other than habitat abundance also may be limiting some wildlife populations. Sustaining species that depend on young forests requires managers be cognizant of more than just the amount of young forests. We demonstrated through simulation modeling that different management practices and natural disturbance regimes create different landscape patterns of tree or stand size classes. Through simulation, management practices can be identified that provide beneficial patch and landscape characteristics for a particular target species. The reality is, however, that even among a small group of focal species habitat and landscape requirements will likely be varied enough that a diversity of practices will best meet the needs of all species. Desired distributions for patch size or landscape composition can be developed based on historic range of variation concepts (Landres et al. 1999), or at the coarser scale by simply ensuring that a diversity of management practices are used within and among landscapes.

Young forests are transient. Without repeated disturbance they are gone 10–20 years after they are created. Fortunately, it is easy to create additional young forests through timber harvest, often with the added economic benefit of a timber sale. Emerging markets for woody biomass may provide new opportunities for creating young forest habitats. Wildfire, weather events, and even insect or disease outbreaks also contribute to the replenishment of young forest habitats. Older forest habitats cannot be recreated as quickly. Consequently, an underlying assumption in our scenarios analyses is that an even distribution of forest area by age class (up to some specified threshold for "old" forests) is desirable. Strictly speaking, increasing the proportion of young forest area (0–10-years old) does not require that attention be given to the distribution of forest area among older age classes; young forest habitats can be recreated from forest of any age or condition. However, the broader underlying intent is to increase or sustain forest biodiversity, and young forest is only one component of a diverse forest age structure. Old forests and middle-aged forests can only be replenished over time via the aging of younger forests. Thus, forest landscapes characterized by non-uniform age class distributions (e.g., negative exponential, bimodal, irregular) present no problems for managers wishing to create additional young forest habitats, but over time perpetuation of non-uniform age class distributions will result in gaps in the quantity of older forest habitats.

The current age class distribution in the Central Hardwood Region is a product of the region's disturbance history. Exploitive timber harvesting that moved east to west was followed by woods burning, livestock grazing, and farming marginally productive lands. Much of the current abundance of forests in the 40–80-year age classes is the result of forest regeneration following abandonment of those practices. The region's current forest age structure is the cumulative effect of many decades of forest growth and disturbance. Increasing the area of young forests can be accomplished very quickly if forest owners and managers are motivated to do so. However altering the current forest age structure—which took many decades to create—to provide a more uniform distribution of forest area across all forest age classes would take many decades of purposeful management and monitoring to accomplish.

Forest ownership patterns in the Central Hardwood Region may prove to be a significant barrier to systematically increasing the area of young forest or to developing a more uniform distribution of forest area by age class (Wear and Huggett, Chap. 16). In the study area 31 million ha or 61% of the forest area is in family forests distributed among 3.5 million private owners. The mean ownership size is small and many owners likely will perceive creation of early successional habitats on their tracts to be at odds with their ownership goals which are weighted toward aesthetics, recreation, and protection. The most efficient options for creating young forest habitats on family woodlands may be in working with the 5% of family woodland owners with forest tracts at least 40 ha in size, because collectively they own 40% of all family forest area in the region (USDA Forest Service 2010).

The coarse filter approach we employed to examine forest age class structure, quantity of young forests, and temporal dynamics of young forests is simplistic but efficient for addressing large geographic extents over long timeframes. We assumed that all forest habitats can be categorized by age class and that there is a link between forest age and habitat characteristics. That may be realistic for young forest habitats 10 years old or younger, but for partially disturbed forests, woodlands, or savannahs the connection between forest age and habitat structure is more tenuous. Those limitations notwithstanding, the coarse filter analyses indicate the magnitude of the young forest resource, its spatial and temporal distributions, and the scope and complexity of some remedies where the amount of young forest habitats is considered to be deficient. The general approach can be used to help set and monitor regional goals for providing young forest habitats. It serves as a starting point for efforts to increase young forest habitats which, during implementation, must also address the more complex issues of where, when, and in what patch sizes to increase young forest habitats for the greatest benefit of different wildlife species that depend on them.

Acknowledgements Forest Inventory and Analysis personnel from the US Forest Service spent 60 years collecting the data we analyzed in this study. Bill Dijak was instrumental in the analysis and mapping of the landscape-scale disturbance scenarios and associated wildlife habitat suitability indices. Two anonymous reviewers provided valuable suggestions that improved an earlier version of this manuscript. We thank them all.

Literature Cited

Backs SE (2010) 2010 spring breeding indices of ruffed grouse. Wildlife management and research notes No. 998, Indiana Division Fish and Wildlife, Indianapolis

Baltimore County (2005) Baltimore county forest sustainability strategy, steering committee final draft. Baltimore County, 128 p. Accessed 23 Sept 2010

Carpenter C (2007) Forest sustainability assessment for the Northern United States. NA-TP-01-07CD. USDA Forest Service Northeastern Area State and Private Forestry, Newtown Square

Cooper TR, Parker K (2010) American woodcock population status, 2010. USDI Fish and Wildlife Service, Laurel

Eyre FH (ed) (1980) Forest cover types of the United States and Canada. Soc Amer For, Washington, DC

Forest Inventory and Analysis (2010a) Data and tools. USDA Forest Service, Washington, DC. http://www.fia.fs.fed.us/tools-data/default.asp. Accessed 23 Sept 2010

Forest Inventory and Analysis (2010b) Forest inventory and analysis national program. USDA Forest Service, Washington, DC. http://www.fia.fs.fed.us/. Accessed 23 Sept 2010

Haufler JB, Melh CA, Roloff GJ (1996) Using a coarse-filter approach with species assessment for ecosystem management. Wildl Soc Bull 24:200–208

He HS, Mladenoff DJ (1999) Spatially explicit and stochastic simulation of forest-landscape fire disturbance and succession. Ecology 80:81–99

He HS, Li W, Sturtevant BR, Yang J, Shang ZB, Gustafson EJ, Mladenoff DJ (2005) LANDIS 4.0 users guide. LANDIS: a spatially explicit model of forest landscape disturbance, management, and succession. Gen Tech Rep NC-263, USDA Forest Service North Central Research Station, St. Paul

Helms JA (1998) The dictionary of forestry. Soc Amer For, Bethesda
Johnson PS, Shifley SR, Rogers R (2009) The ecology and silviculture of oaks, 2nd edn. CABI Publishing, Wallingford/Oxfordshire
Landres PB, Morgan P, Swanson FJ (1999) Overview of the use of natural variability concepts in managing ecological systems. Ecol Appl 9:1179–1188
Mladenoff DJ, He HS (1999) Design and behavior of LANDIS, an object oriented model of forest landscape disturbance and succession. In: Mladenoff DJ, Baker WL (eds) Advances in spatial modeling of forest landscape change: approaches and applications. Cambridge University Press, Cambridge
Miles PD (2010) Forest inventory EVALIDator web-application version 4.01 beta. USDA Forest Service Northern Research Station, St. Paul. http://fiatools.fs.fed.us/Evalidator4/tmattribute.jsp. Accessed 1 Nov 2010
National Archives and Records Administration (2007) The president: executive order 13423 – strengthening federal environmental, energy, and transportation management. USA Federal Register, 26 Jan 2007, 3919–3923
Oliver CD, Larson BC (1990) Forest stand dynamics. McGraw-Hill, New York
Rittenhouse CD, Dijak WD, Thompson III FR, Millspaugh JJ (2007) Development of landscape-level habitat suitability models for ten wildlife species in the Central Hardwoods Region. Gen Tech Rep NRS-4, USDA Forest Service Northern Research Station, Newtown Square
Sauer JR, Hines JE, Fallon J (2008) The North American breeding bird survey, results and analysis 1966–2007. Version 15 May 2008. USGS Patuxent Wildlife Research Center, Laurel
Schulte LA, Mitchell RJ, Hunter ML Jr, Franklin JF, McIntyre RK, Palik BJ (2006) Evaluating the conceptual tools for forest biodiversity conservation and their implementation in the US. For Ecol Manage 232:1–11
Shifley SR, Thompson FR III, Dijak WD, Larson MA, Millspaugh JJ (2006) Simulated effects of forest management alternatives on landscape structure and habitat suitability in the Midwestern United States. For Ecol Manage 229:361–377
Smith WB, Miles PD, Perry CH, Pugh SA (2009) Forest resources of the United States, 2007. Gen Tech Rep GTR-WO-78, USDA Forest Service, Washington, DC
Spencer Jr JS (1969) Indiana's timber. Res Bull NC-7, USDA Forest Service North Central Forest Experiment Station, St. Paul
Tirpak JM, Jones-Farrand DT, Thompson III, Twedt DJ (2009) Multi-scale habitat suitability index models for priority landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas bird conservation regions. Gen Tech Rep NRS-49, USDA Forest Service Northern Research Station, Newtown Square
Twedt DJ, Tirpak JM, Jones-Farrand DT, Thompson FT III, Uihlein WB III, Fitzgerald JA (2010) Change in avian abundance predicted from regional forest inventory data. For Ecol Manage 260:1241–1250
USDA Forest Service (1953) Forest statistics of Indiana. Forest survey release No. 15, USDA Forest Service Central States Forest Experiment Station, Columbus
USDA Forest Service (2004) National report on sustainable forests – 2003. FS-766, USDA Forest Service, Washington, DC
USDA Forest Service (2010) National woodland owner survey. USDA Forest Service, Washington. http://www.fia.fs.fed.us/nwos/. Accessed 31 Oct 2010
Woodall C, Hansen M, Brand G, McRoberts R, Gallion J, Jepsen E (2006) Indiana's forests 1999–2003 (Part B). Res Bull NC-253B, USDA Forest Service North Central Research Station, St. Paul
World Commission on Environment and Development (1987) Our common future. Oxford University Press, New York